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Salt Spray Test

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I. Introduction

The corrosion of metals has been an absorbing study of countless investigators for many years. In order to acquire more rapidly knowledge of the fundamental causes and processes of corrosion, and to obtain facts indicative of the probable behavior of metals under various conditions of service, numerous laboratory methods for accelerating attack have been devised. One of these, the subject matter of the present paper and popularly known as the "salt spray test", has enjoyed increasingly widespread use in this country.

At the present writing the procedures employed in salt spray testing differ appreciably in different laboratories.

Owing to this lack of uniformity, and to the failure to control essential variables associated with the method, the test itself has been subjected to some unjust criticisms. There has consequently arisen a demand for standardization of method. As the National Bureau of Standards was among the first to utilize the test and has played a prominent role in its development, it would seem appropriate that suggestions toward that end be made from this source. With this in view the important factors influencing the corrosion of metals by this means will be discussed, and the procedure and equipment used in this and in a few other laboratories will be described.

II. Historical

The salt spray test was originated a little over 25 years ago by Capp, whose first published description appeared in 1914.^{(1)*} His interest lay in the behavior of certain metallic protective coatings that were intended for use under seacoast conditions. It is noteworthy that Capp recognized that, "the only final test of the efficiency of a given type of coating is actual exposure to the same sort of influence that the material is supposed to resist in service." He therefore exposed his test specimens to a mist formed by atomizing saline solutions. This constitutes the basic feature of all salt spray tests.

Shortly thereafter the National Bureau of Standards became interested in the possibilities of the test and much of the pioneer development work was done here by Finn⁽²⁾ who opined that "The salt spray test approaches a practical corrosion test more closely than any other so far described." Subsequently Rawdon, Finn and Grossman⁽³⁾ utilized the method in a study of metallic coatings on ferrous materials.

Sub-Committee III of Committee B-3 of the American Society for Testing Materials (H. S. Rawdon, Chairman) undertook an intensive study of the salt spray test in connection with its investigation of the Corrosion of Non-Ferrous Metals and Alloys and periodically published its findings^(4, 5, 6, 7, 8, 9, 10) and those of other investigators.

In its earlier applications the test was used largely for the study of protective metallic coatings, especially those of zinc on ferrous materials. In its initial use as an acceptance test in specifications⁽¹¹⁾, zinc coatings were required to withstand 100 hours' exposure to a 20-percent salt spray, at room temperature, without any evidence of rust. The salt spray test has been incorporated into a large number of government specifications, especially those of the Army and Navy Departments, which fact has been largely

*(1) Cf. Bibliography

responsible for its extensive use in industry. The agencies named have specifications(12, 13), embodying recommendations of the National Bureau of Standards, which describe detailed requirements for the apparatus, material, and procedure to be used in the salt spray corrosion test of metals for aircraft use. Most of the existing boxes are built in accordance with these specifications.* They aim toward what is now considered ideal conditions of testing, namely, to expose specimens to a uniformly distributed dense mist or fog, of unchanging composition, and at a constant temperature. These factors will now be considered in more detail.

III. Operating conditions

1. The spray

a. Formation and distribution

In all salt spray apparatus it is customary to form the mist by a device patterned after those shown in Figure 1, termed the atomizer or nozzle. This consists of two nipples, usually placed at right angles to each other. Compressed air, saturated with moisture, is sent through the horizontal nipple, and tends to create a vacuum which draws the solution to the top of the vertical nipple, where it is "atomized".

The fact that air pressure is involved in the atomizing gives rise to directional effects, as a strong stream of spray is directed from the nozzle. In order to prevent this stream from impinging on the specimens, it must either be directed away from them or else made first to strike a baffle plate. Air currents necessarily result, which may result in more severe corrosive action in some parts of the chamber than in others. For this reason the operating pressure should be held to the minimum compatible with efficient production of spray.

It is necessary to provide vents, to prevent an increase of pressure within the chamber, and these may likewise influence the distribution of the spray. Such venting has been done more or less indiscriminately, but it warrants much more serious consideration than has usually been given, if directional effects are to be avoided.

These vents sometimes permit the spray to escape directly into the room housing the apparatus. Although this does not affect the test directly, it is very undesirable, because deposits of salt on auxiliary equipment are not only unsightly, but corrosive. It is preferable to provide an exhaust duct from the vents to conduct the mist outdoors.

*Copies of these may be obtained from Chief, Materiel Division, Air Corps, Wright Field, Dayton, Ohio, or from the Naval Aircraft Factory, Philadelphia, Pa.

b. Atomizers and operating pressures

Two principal types of atomizers or nozzles are used. These will be referred to as the low-pressure and high-pressure nozzles. Low-pressure nozzles made of glass (Figure 1a) and operated at a pressure of from 10 to 15 lb./sq. inch have proved highly satisfactory, and are the only ones now used at the National Bureau of Standards. The high-pressure nozzles (Figure 1b) that are also permitted in government specifications are operated at 25 to 50 lb/sq. inch pressure, and are usually constructed of hard rubber or monel metal.

The preference for the low-pressure nozzle is based upon the desire to minimize the velocity of air currents in the chamber. Also, with a lower velocity of the air, less difficulty is to be expected with deposition of salt at the nozzle, which may prevent continuous operation. However, since breakage or clogging of nozzles may occur, it is advisable to have at least two in each chamber, to guard against interruptions.

c. Density of the fog

According to the size and number of specimens to be tested, salt spray cabinets may vary greatly in volume, for example from 5 to 1000 cubic feet. Some industrial laboratories use a relatively large room as a salt spray chamber. It is probable that the dimensions of the spray chamber are relatively unimportant so long as the fog is sufficiently dense to wet uniformly the surfaces of the test specimens. The film of liquid should be fairly thin so that "very few, if any, drops of sensible size form on the objects"(1). One atomizer, of either the low- or high-pressure type, will give sufficient mist to operate chambers having capacities of approximately 6 cubic feet or less. The Army and Navy Specifications demand a capacity of nearly 12 cubic feet, which requires two low-pressure nozzles, though one high-pressure nozzle has been reported to be satisfactory.(10) In boxes of larger size, additional atomizers may be required. As a rule, a larger number of low-pressure than of high-pressure nozzles will be needed.

In order to minimize variables it may be desirable to specify definite sizes for small, intermediate, and large chambers, with vents, nozzles and baffles located correspondingly in all chambers.

There is a definite need to specify the density of the fog in the chamber and a means for its determination. Experiments directed toward that end are shortly to be begun at this Bureau. The density of the mist unquestionably varies considerably in the boxes of different laboratories, and even, from time to time, in the same box, depending, as it does, upon the air pressures used, the dimensions of each orifice and their distance apart.

2. The solution

a. Purity

Capp(1) was careful to point out that "the salt spray test is only an exaggeration of what may be expected at the seashore and differs only in degree, not in kind, from the normal conditions under which the article is to be used". Hence, the use of saline solutions to simulate sea-coast conditions was originally, and still is, the prime objective of the test. Other chemicals have been used, for special purposes(4)(6)(14)(20) in salt spray equipment, but these will be disregarded in the present discussion, since too often the objective of simulating an actual service condition is overlooked entirely.

Numerous laboratories have tried to use actual seawater, or artificially prepared solutions of comparable composition, but at present this is done only to a very limited extent and in special cases. The inability to secure these solutions of constant and reproducible compositions led Somers(9) to label the attempt "unsound practice".

It has therefore become customary to use only sodium chloride as the corroding agent. Since small amounts of impurities have been found to influence markedly the rate of attack, the use by all laboratories of a chemically pure grade of sodium chloride cannot be too strongly urged. To eliminate variables further, only distilled water should be used in preparing the solution, as there are great differences in the composition of natural waters in various localities. It is also advisable to maintain an approximately neutral solution, having a pH around 7.

b. Concentration

Many Government specifications ~~all~~ require the use of a solution consisting of 20 parts by weight of sodium chloride and 80 parts by weight of distilled water, the concentration originally recommended by Finn(2). Capp(1) had initially used a saturated solution but, owing to the tendency for salt to precipitate at the nozzle, later changed to a 3-percent solution. Finn reasoned that the concentration should be as high as compatible with an insured continuous operation and hence selected the 20-percent solution. Somers(9), then of the Aluminum Company of America, correctly stated that "The strength of the 20-percent salt solution can be maintained within narrow limits and a larger background of experience has been built upon its use than has been built on any other concentration. The specific objection to its use is the tendency of solid salt to deposit on the specimens and around the spray nozzle but this effect in reality only indicates improper functioning of the apparatus, that is, the incoming air is not saturated, the proportion of air to solution is

too great, or that the tube from the solution to the nozzle is stopped up. In other words, as soon as the amount of concentration of the solution in the mist is too low this effect shows up, where with lower concentrations of salt an appreciable time might pass while the concentration of solution on the specimens was building up to the saturation point of salt before any trouble could be noted."

Experience has indicated that there are no marked differences in the rate of corrosive attack between the 20-percent solution and those of lower concentrations, though there is a trend toward slightly greater acceleration by the former. If the results obtained in various laboratories are to be strictly comparable, it is essential that all should use identical solutions. Since there is little likelihood that present government specifications with respect to the 20-percent concentration will be changed, and because both experience and logic point toward its use, that solution should be the one selected.

3. Temperature

a. The need for control

The temperature at which a salt spray test is conducted constitutes a variable which until recently has received little consideration. In 1924, Rawdon⁽⁴⁾ suggested the use of $30^{\circ}\text{C} \pm 1^{\circ}\text{C}$ and again⁽¹⁵⁾ in 1928 sounded a warning against the use of the test under temperature conditions varying over a wide range. Such advice has been quite commonly ignored and it has been almost universal practice for the test to be run at room temperatures. Cases have even been known where the equipment was set up outdoors or in unheated quarters and the temperature ranged from extreme summer heat to severe winter cold.

There is a definite and serious need for agreement on the temperature at which these tests should be run. The actual temperature is relatively immaterial providing it be constant and universally accepted and used. Obviously the specified temperature must be one quite readily maintained with the minimum of auxiliary equipment. Government specifications based on the work of the National Bureau of Standards require a temperature of 95°F ($35^{\circ}\text{C} \pm 2^{\circ}\text{C}$).⁽¹⁶⁾ This temperature was selected because it can be readily maintained in temperate climates at the maximum summer heat without cooling equipment, and maintained in winter with simple heating equipment.

The simplest way in which to control the temperature in the box is to keep it in a constant temperature room. This avoids contact of the heater and thermo-regulator with the corrosive salt spray, and eliminates gradients within the box. Owing to the slight cooling caused by expansion

of the air in passing through the atomizer, the temperature within the box is usually 1° to 2°C below that in the room. The latter should therefore be maintained at a slightly higher temperature, such as 36°C (97°F).

b. Results of non-control

A cooperative test by two government laboratories and two commercial laboratories was sponsored by this Bureau to determine the effects of variations in temperature. The tests were run on bare 17ST sheet duralumin (.040 inch), subjected to 20-percent sodium chloride spray. The extent of corrosion was determined by the loss in elongation. In Figure 2 are presented curves showing the daily temperature readings reported in the four laboratories during the test period. The only one of these laboratories maintaining a constant temperature was the National Bureau of Standards. From these curves it is evident that tests run at station 1 would not even approximate those run at station 4. The temperature variations in normally heated laboratories shown in curves 2 and 3 of Figure 2 indicate definitely that there is too much uncertainty in "room temperature" in a modern laboratory to warrant tests under these conditions.

Figure 3 shows the loss in elongation for two test periods covering summer and winter conditions for the co-operating laboratories. It will be noted that there was a definite tendency for the initial rate of corrosion to increase with rise in temperature. The designated temperatures represent the averages for the period plotted. Where these average temperatures were not similar, poor check results were obtained. At station 1, the low winter temperatures even caused changes in the slopes of the curves. Station 3, using a high-pressure nozzle and a box of special design, gave the greatest deviation. The constant temperature box, No. 4, duplicated its own performance quite closely.

IV. Salt spray cabinets

1. Typical system

The essential features of a typical salt spray system are illustrated in Figure 4. It has been a general practice to construct the boxes of alberene stone, although slate, glass, wood, or other non-metallic materials have been used. Porous materials like wood require a waterproofing coating. Good bituminous paints have proved most suitable for this purpose. Recent developments in the application of protective coatings such as rubber, have made metals available for constructing the boxes. These have the advantage of being easier to form and less fragile than the above materials.

Some device, such as a dam, is used to prevent contamination of the original solution by the condensed spray. Drains are provided to empty each sump. The nozzles are located in the front of the box facing a glass baffle, and

ordinarily a single vent is placed in the rear. Notches are cut in the sidewalls to provide support for racks.

The cover may be made of any inert or well coated material. Usually a gasket, which is made integral with either the cover or box, is placed between the cover and the box, in order to prevent leakage of the spray. Sponge rubber sheet, an inch thick, is the most satisfactory gasket material. Somewhat inferior results are obtained by the substitution of metal-cored rubber tubing.

The air is passed through a series of cleaning towers, to remove oil, then through a saturating tower, and thence to the atomizer. The size of the cleaning towers is dependent on the volume of air used. The saturating tower must contain a sufficient height of water to insure nearly complete saturation of the air passing through. The water in the saturating tower should be at about the same temperature and pressure as the spray box, in order to saturate the air under the same conditions at which it is to be used. This saturation also compensates for the water removed from the air on compression, and prevents incrustations of salt from forming on the atomizers.

2. Details for construction

a. Army-Navy specifications

The system described in Army-Navy Specification No. AN-9185 for Salt Spray Process for Accelerated Corrosion Test (Aircraft Use) has been widely used. A detailed drawing for the construction of this equipment(12) is shown in Figure 5. It will be noted that the method of storing the solution and providing for drainage of condensed spray may be varied.

The most serious disadvantage of this type box arises from directional effects, already discussed. It is also very difficult to maintain tight gaskets and to prevent the escape of spray from the box into the room.

The Aluminum Research Laboratories Salt-Spray Box(10) (Figure 6) also conforms to the Army-Navy Specification but differs somewhat in design, mainly in the materials of construction and in the venting. An effort was made to minimize directional effects, either by using three vents, 1 inch in diameter and about 2 inches from the top along each side, or by allowing a small clearance between the lid and the box. This method, of course, allows the spray to escape into the room. The box is constructed of aluminum and painted with P-27(17) type (zinc chromate) primer and two coats of bakelite-aluminum paint. A high-pressure nozzle (Figure 1b) constructed of hard rubber is used. The air is cleaned by passing it through a tower filled with "activated alumina". No water-saturating column is used. The

salt spray equipment of this laboratory is at present operating at room temperature but plans have been made to operate it at 35°C (private communication).

Several experimental boxes have come to the authors' attention which embody quite radical changes from the usual design. It is felt that, in view of the many years of experience with the present type box, the development and acceptance of new designs should be gradual.

b. Bureau of Standards equipment

An improved design of the, more or less, conventional type box has recently been adopted at the National Bureau of Standards. The box affords greater ease of operation, minimizes directional effects, and precludes spray leakage. A detailed drawing of the box design is given in Figure 7. The box is constructed of 3/16" steel, with all joints welded, and is coated both inside and outside with 1/8" of hard rubber. The box is maintained in a horizontal position and the dam and drainage are provided by a "V" bottom. The sump in the front is of sufficient size to allow the atomizers to be directed away from the specimens and against the front of the box, which thereby serves as a baffle plate. An inverted bottle containing reserve solution is supported over the well in the box so as to maintain a constant solution level. The vent is located in the bottom, toward the rear of the box, and is larger than is normally used. This also serves as a drain for the spent solution, as it is connected both to an exhaust stack and to the sewage system. The tendency is for the spray to pass over and down the specimens, thus producing a much more uniform attack than is obtained in the old box. Two low-pressure atomizers are used (Figure 1a).

The principal novel feature of the box is the elimination of leakage at the cover by the use of a water seal. The heavy cover is hung from the ceiling by pulleys, and counterbalanced to facilitate raising and lowering. The cover does not slope, because actual operating experience has shown that no spray condenses on the cover of this box, above the specimen chamber, and therefore there is no danger of drippage onto the specimens. A small glass window in the cover, sealed with asphalt-asbestos roofing compound, permits observation of the density of the fog at that point. Subsequent experience may justify the insertion of several small windows, especially in larger boxes.

c. High temperature equipment

Boxes have also been designed to operate at elevated temperatures, either for purposes of greatly accelerating the rate of attack, or to simulate special conditions of application. Capp(1) mentioned the possibility of using a steam jet in this connection. A box with electric heat-

ing elements that is in use at the Naval Engineering Experiment Station, Annapolis, is shown in Figure 8. The high temperature naturally favors deposition of salt at the nozzle, so it is necessary to provide special means for keeping the tip wet, as shown in Figure 8.

V. Procedure in testing

1. Cleaning

The following discussion of the procedure employed in salt spray testing is based largely on experience at this Bureau. All uncoated materials should be degreased before being placed in the box. The use of pickling solutions, abrasives, and like materials for the removal of foreign matter from the surface may defeat the object of the test. As a general rule, no method of cleaning should be used which in any way alters the character of the surface of the metal. The preferred methods of degreasing entail the use of organic solvents as benzol, carbon tetrachloride and trichloroethylene, applied, for example, in "vapor degreasers".

2. Type of specimen

In charging a salt spray box the shape of the articles to be tested must be considered. If specimens are prepared especially for the test, they should be of simple design, readily suspended, and free of water "traps". When it is necessary to test entire fabricated articles, care must be taken to provide adequate drainage, and a minimum of contact points with the racking material. If only portions of coated articles are to be tested, the areas exposed in cutting the specimens should be protected with paraffin or a bituminous paint.

3. Methods of suspension

All materials used for fixtures such as racks and supports, should be non-metallic, or covered with non-metallic coatings. It is customary to suspend the specimens vertically from rods supported in the slots in the sides of the box. Dowel pins impregnated with paraffin are also used.

The specimens may have holes drilled near their tops, through which paraffin-impregnated cord may be looped and fastened to the rods. If only a few specimens are to be tested they should be placed in the center of the box. When more than one rack is used, they should be uniformly spaced in the box, working outward from the center.

4. Movement of specimens

To obviate directional effects the positions of the specimens should be interchanged in the box. The cycle of interchange should be so planned that each rack of specimens occupies each position for a like interval of time. Daily movement of the specimens will usually meet this requirement. For example, the specimen or, if a number of specimens are assembled on a rod, each rod of specimens, should be rotated through 180° and also moved forward while the rod in the front position is moved to the rear.

5. Starting the tests

The solution reservoir must be thoroughly cleaned before starting the test. It should be filled with fresh solution which, regardless of composition, should be filtered. The atomizers should then be started and, after they are operating properly, the cover of the box put in place. An air gage and regulating valve (an ordinary gate valve may be used) should be placed on the air line just outside the box for maintaining the proper air pressure. When using more than one box, the pressure in the low-pressure air line should be kept about 5 lb./in.² higher than that required for operating the atomizers. This allows for adjustment at each individual box.

The air compressor should have ample capacity and be sufficiently rugged to operate for long periods with only care for oiling at regular periods, and for minor adjustments. The air is delivered to a suitable storage tank in which a pressure of about 80 lb/in.² is maintained. A reducing valve then serves to regulate the pressure in the service line, usually at 15 to 20 lb/in.²

6. Inspection

The boxes should be opened and inspected daily but, if the tests are of long duration, this may be omitted on Sundays and holidays. The concentration should be checked and regulated by the specific gravity which, according to Army and Navy Specifications, should be maintained at 1.151 at 16°C. The solution should be replenished at each inspection. The vents and exhaust stacks should be flushed out weekly.

Salt spray equipment, once started, should operate continuously, at least throughout the duration of the test. Intermittent operation, and various cycles have been proposed, and in some cases used to simulate special conditions of exposure. However, this introduces another variable in the procedure, and for that reason is not to be recommended. In any event, correlation of the results obtained by continuous and intermittent tests is impracticable.

7. Temperature control

Constant temperature is obtained at this Bureau by maintaining an inside room, which houses several boxes, at 95°F (35°C). Control is effected by means of electrical heating elements and thermostats. Uniformity of temperature is obtained by properly localized heating units and fans; thermometers placed 6 inches from the floor, at box level, and at the ceiling give temperature readings within the limits of 35°C ± 2°C.

VI. Typical applications

The salt spray test is frequently used to determine differences in corrosion-resistance of a given material, in various conditions of fabrication, heat treatment, etc. An outstanding example is the aluminum alloy, duralumin. Certain improper heat treatments render this alloy susceptible

to intercrystalline attack, which is highly undesirable. A few days in the salt spray are sufficient to determine definitely, by subsequent microscopic examination of cross-sections, whether the material is susceptible to such attack. In a purely qualitative manner it is often possible to determine whether one material is more susceptible to attack under saline conditions than another. Attempts to express quantitatively how much better one material will be than another, under particular service conditions, are usually unsuccessful. Only for materials which are essentially similar in chemical composition can approximate predictions be made.

The salt spray test is used to a considerable extent to determine whether a material will prove satisfactory for certain purposes, to resist saline conditions. With a proper background of research and experience it may be possible to specify a minimum time over which material must remain unattacked or be attacked to a predetermined maximum extent in the salt spray. The Army and Navy specifications for anodic coatings on light alloys(18)(19) for example, are based on the behavior of the coatings after a period of 30 days' exposure in the salt spray test. Similar specifications for electrodeposited(21) metal coatings form interesting applications of the test.

VII. Methods of measuring and expressing results

The methods of evaluating and interpreting the results of a salt spray test are as important as the equipment and the procedure used. Of course, the problem of evaluating results is not peculiar to the salt spray test alone, but is inherent in all types of corrosion tests. The methods, in general, utilize either direct or indirect means for measuring the extent of corrosion. The direct methods estimate the extent of the corroded areas. Visual examination is used in many instances, supplemented at times by attempts to estimate the actual or proportional area attacked. A count of the corroded spots and/or approximate measurements of their areas and depths are frequently made. Such measurements may be made on the entire specimen, macroscopically, or microscopically, on suitably magnified cross-sections. Determinations of the loss in weight and of changes in tensile properties, are the two indirect procedures most commonly employed, to determine the extent of corrosion.

It should be emphasized that the method to be chosen for evaluating corrosion is largely dependent upon the material being tested and the specific type of information desired. If materials of widely different chemical composition are being tested, the direct methods of measuring corrosion are indicated. If materials of similar composition are being compared, such as duralumin with aluminum alloys

of similar compositions, the indirect methods are usually applicable. For these particular alloys experience has shown that the loss in elongation may be used as a criterion of the attack. On materials which have a low initial elongation this method may be useless, in which case loss in tensile strength may give valuable information. Actual tests should be made to determine the method of evaluation best suited to the particular purpose, instead of indiscriminately applying any one of the methods cited.

When the purpose of the test is to determine the relative efficiencies of protective paint coatings or of electrodeposited coatings, visual examination, or measurements of the areas attacked are generally preferred.

VIII. Interpretation of results

Irrespective of the method chosen for expressing the results of a salt spray test, considerable caution must be exercised in their interpretation. The human equation must be guarded against and personal prejudices eliminated. It must always be borne in mind that the results are strictly applicable only to the conditions existing within the salt spray chamber during the test. Hence, attempts to predict the service life of a material in a specific locality are entirely unwarranted. For example, the material may behave quite differently in an inland industrial atmosphere than it did in the salt spray box.

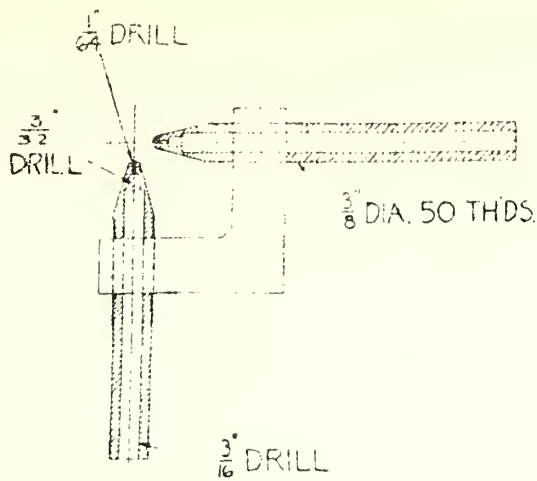
It frequently is possible to obtain valuable information respecting the probable relative behavior of two materials intended for use in marine atmospheres, or under saline conditions. It was solely for this purpose, in fact, that the test was originally devised.

Before predictions of probable behavior in service can be hazarded, it is essential that repeated correlations be made between the results of the accelerated test, and actual weather exposure under service conditions. Complications may also arise from other variables, such as the design of specific articles. For example, crevices may entrap moisture, and give rise locally to unusual conditions and to a more severe attack. In the case of protective paint coatings, differences in the amount and intensity of sunshine at different localities may exert a predominating effect on their behavior, which is then unrelated to the direct effect of the saline solution.

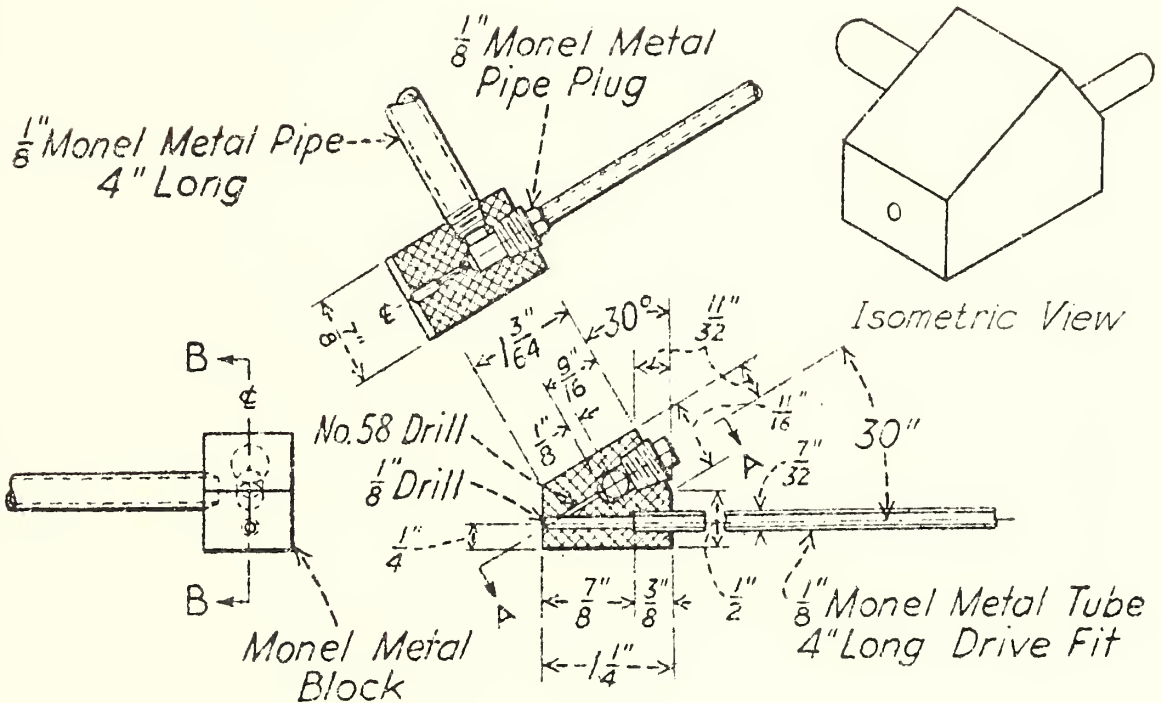
In general, the salt spray test, when intelligently used, represents a laboratory test of considerable value. To point out some of its shortcomings, and to emphasize the urgent need for uniformity of testing procedures, is the prime objective of this discussion.

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a.



b.

Fig. 1. - Shows plans for atomizers (or nozzles) commonly used in the salt spray test.

a. - Low-pressure type, usually made of glass or hard rubber.

b. - High-pressure type, usually made of hard rubber or Monel metal.

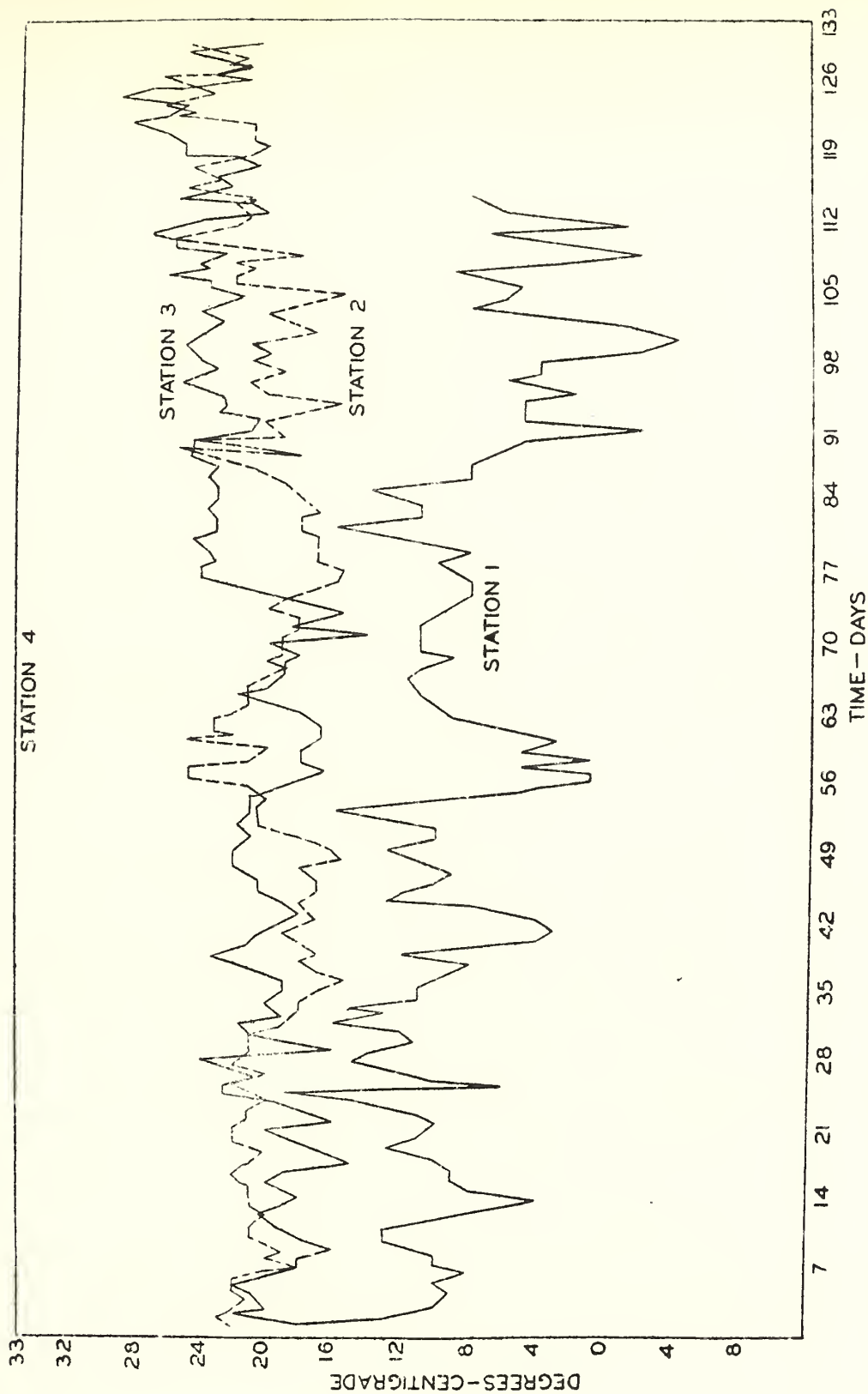


Fig..2. - The curves illustrate the wide temperature variations, during identical test periods, at four different laboratories. Data were plotted on the basis of the average of two daily temperature readings, not necessarily the maximum and minimum. At Station 4 control of temperature was maintained, while at the remaining stations the tests were conducted under "room temperature" conditions.

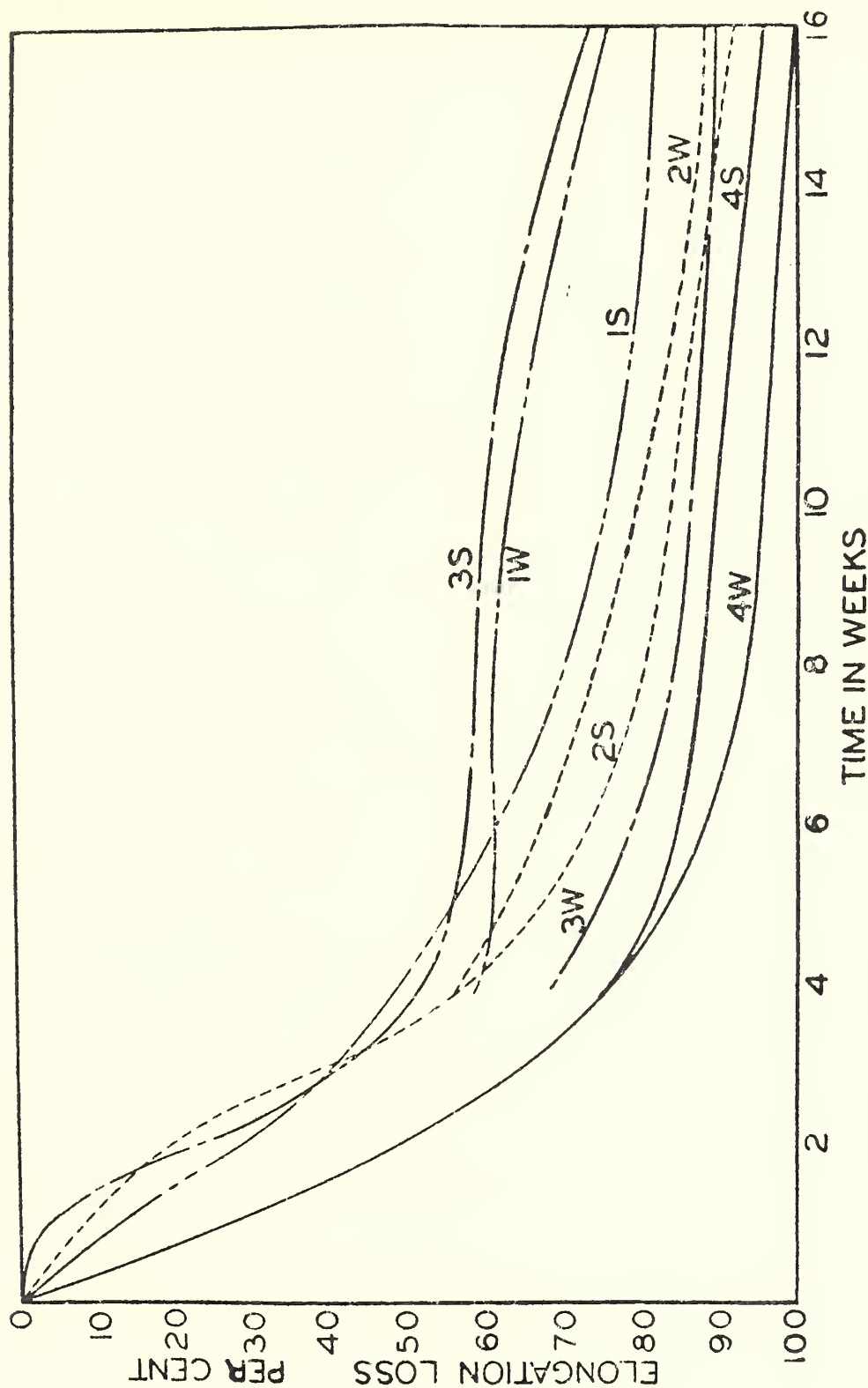


Fig. 3. - Results obtained at Stations 1, 2, 3, and 4, during summer (S) and winter (W) salt spray tests on duralumin specimens. Note especially the poor agreement for the two seasons at Stations 1 and 3, and the good agreement at Station 4, where a temperature of 35°C was maintained. Average temperatures, based on twice daily readings, do not generally picture the prevailing conditions. The average for each Station for the summer and winter tests, respectively, were (°C): 1. - 21, 8; 2. - 27, 19; 3. - 22, 21; 4. - 35, 35.

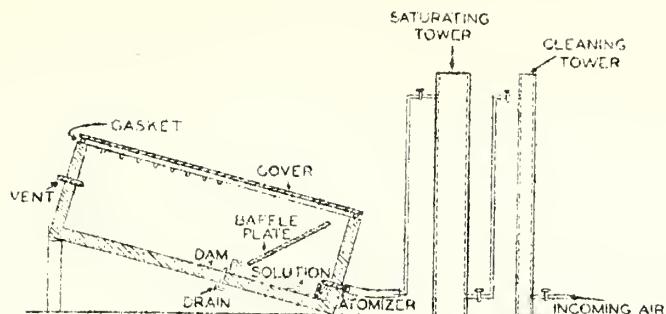


Fig. 4. - Shows the more essential features of a typical system of installation for the salt spray test.

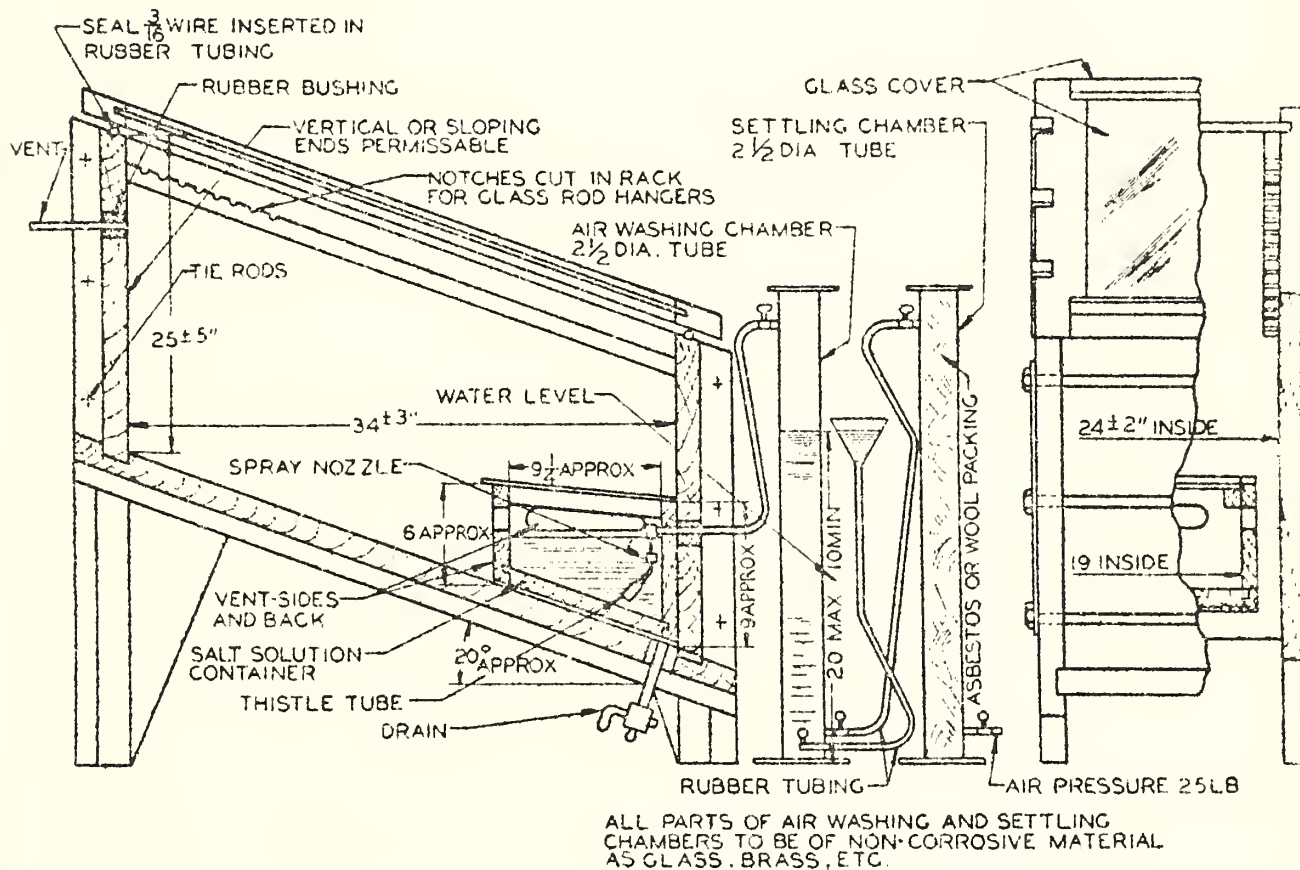


Fig. 5. - Shows details of design of salt spray apparatus as depicted in U. S. Army Department Specifications.

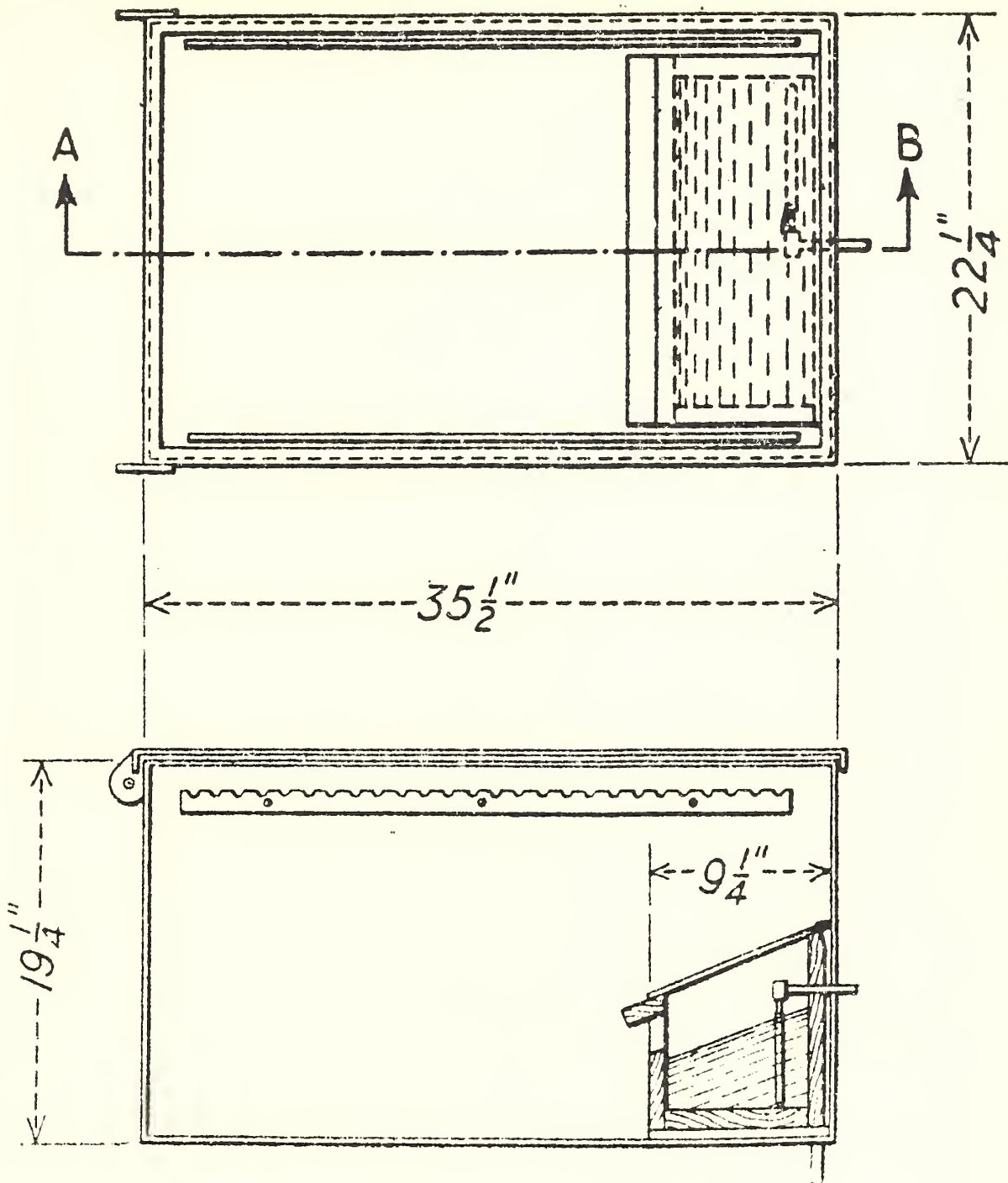


Fig. 6. - Sketch showing general plan of the salt spray box used at the Aluminum Company of America Research Laboratories.

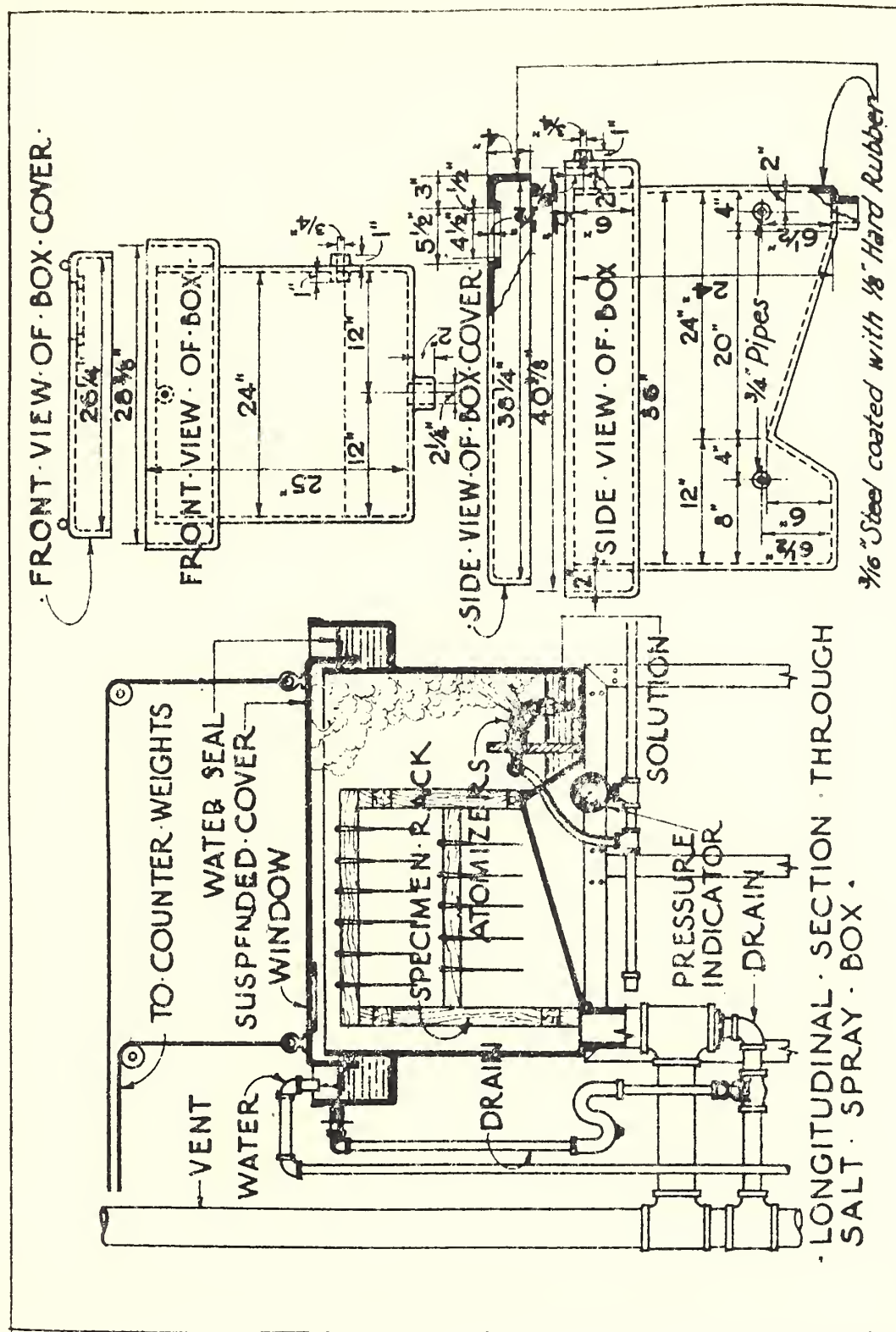


Fig. 7. - Shows details of design of salt spray box used at the National Bureau of standards.

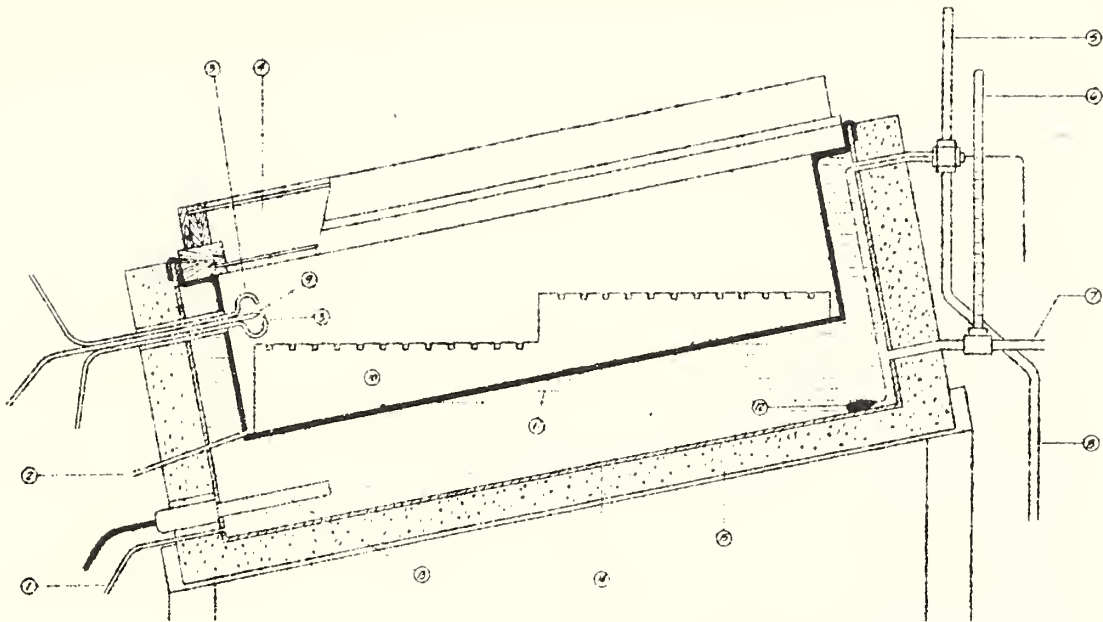


Fig. 8. - Shows general features of a salt spray chamber adapted for use at elevated temperatures, and used at the Naval Experiment Station. The numbers indicate:- 1 - fresh water drain; 2 - salt water drain; 3 - salt water nozzle; 4 - double glass cover; 5 - vent; 6 - water column; 7 - fresh water inlet; 8 - over-flow; 9 - air nozzle; 10 - soapstone specimen rock; 11 - sheet lead; 12 - thermostat regulating element; 13 - heating chamber; 14 - sheet steel; 15 - cork insulation.

